A STUDY OF THE DEVELOPMENT OF THE CHARACTERS OF THE FLEECE DURING GROWTH IN THE DIFFERENT REGIONS OF THE BODY

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(With Plates III–VI and Five Text-figures)

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INTRODUCTION

It is not our intention to give a complete account of the literature on the subject, but we shall refer simply to those papers which seem to have a direct bearing upon the facts observed.

Duerden & Ritchie (1924) studied the development of the fleece in the South African Merino. Wildman (1932) made a very complete study of the coat of the foetus in several breeds, and he concludes that there are no differences in the mode of development. We must note, however, that this investigation is not based upon the real age of the foetuses but upon the relative lengths of the individuals examined. He mentions differences found in foetuses that were twins and therefore of the same age. Galpin (1935) concluded from an examination of the coat of the foetus that the follicles of the fibres of the various regions develop at different times and that each region is a local determiner of its own development; she also suggests that "depression" in the potentiality in growth of the fibre is a local phenomenon. Iljin (1926) found that in the Himalayan rabbit each region of the body reacted differently to low temperatures, allowing recessive colour characters to appear in the hair covering the region concerned. He also recorded (1930) similar findings for the Siamese cat. The same author (1936) found that well-defined regions of the skin react differently, as regards the shedding of the fibres, to doses of thallium acetate injected; he concluded that different centres of keratinization exist in the body. Thomasset (1936), in a study of the variations in the fibres of wool grown during the course of a year on the shoulder and on the thigh, observed that the variations do not exhibit the same intensity everywhere—which seems to indicate a certain independence of these regions in the mode of reaction to environmental agents, a fact which is in agreement with the idea of the existence of "centres of keratinization" acting with a certain degree of independence. The same author (1937), studying the inheritance of the fleece characters in a Romney-Lincoln cross, arrived at the view that the inheritance of the fleece characters differ according to the regions of the skin, and that the way in which these characters are manifested may depend upon the late or early development of the region in question.

One must also note the differences of opinion among certain writers as to the distribution of the qualities of the fleece in different regions of the body. These differences of opinion are very probably due to real differences in the way in which the qualities of the fleece are distributed throughout the body. In breeds derived from recent crosses or crosses not yet fixed, e.g. the Corriedale and certain hybrid sheep, these differences are very pronounced from one region to another. Any investigation tending to elucidate the reason for these differences from one region to another from the physiological and genetic standpoint should, we believe, throw some light upon the interpretation of the relation that exists between the phenotype and the genotype of the animal. From the practical standpoint these investigations are obviously of interest, since they help to elucidate the problem of the homogeneity of the fleece and the problem of sampling to estimate the value of the fleeces of animals for breeding.

The points studied in this investigation are: (1) which of the four regions of the skin—the shoulder, the leg, the belly and the tail—exhibits the earliest development and which the latest; (2) the relation existing between the relative earliness of the development in these regions and the nature of the fibres which develop upon them; and (3) which is the best suited region in a given stage of development at which to judge the qualities of the fleece.

MATERIAL AND METHODS

The subjects studied were two twin lambs (shown at different stages of development in Pl. III, figs. 1*a–d*, 2*a–d*, born at the Animal Research Station, Cambridge, from a Suffolk ♂ × Suffolk (Border Leicester-Cheviot) ♀ cross.

One of these two lambs, No. 55, Pl. III, fig. 1, was completely covered, except for a small area over the shoulder, with long black hair at birth, and slowly lost this as it grew older. The other (No. 54, Pl. III, fig. 2) was shorter in fleece and not so dark in colour, and became white much more quickly as it grew older. Samples of wool were taken from these lambs every two months, by shearing close to the skin from the following regions: shoulder, leg, belly and tail.

The samples were washed by immersing them for about 10 min. in two successive baths of xylol, and were then mounted with Canada balsam, and microscopically examined by transmitted light at a magnification of 540 diameters. The fibres were subsequently measured with an ocular micrometer on which 7·5 divisions $= 10\mu$. While measuring the fibres those which had any peculiarities such as medulla, colours, etc., and the degree of the peculiarity (medulla, more or less thick, colours of a greater or lesser intensity) were noted. As regards the shades of the coloured fibres, an estimation was made by eye according to an arbitrary scale ranging from white to deep black.

A macroscopic examination was made of the different types of fibres (especially in the tail region) also, by sorting them out with special forceps on a black or white background, according to the colour necessitated by the colour of the fibres.

I. THE RELATIVE DEVELOPMENT OF THE FLEECE IN THE DIFFERENT REGIONS OF THE SKIN

The Suffolk is a breed in which the lambs are black at birth and the colour of the fleece changes to white as the lamb grows up. Examination of Pl. IV*a*, *b* and *c*, showing respectively the shoulder, leg and belly of lamb No. 54 and of Pl. V*a*, *b* and *c*, showing the shoulder, leg and belly of lamb No. 55, show very clearly that as regards earliness of development one can class the regions observed in the following order: shoulder—leg—belly. The same conclusion can be drawn from an examination of Pl. III, figs. 1*a*–*d*, 2*a*–*d*. The tail shown in Pl. VI comes after the belly and is the latest region of the body.

The criterion used for judging the relative earliness of a region is the quantity of coarse and coloured hairs of the birthcoat found in the region examined, and the rapidity with which these disappear.

Since these types of hairs are present in the fleece of the young animals and disappear when the animal has reached the adult stage, one may conclude that they are characteristic of definite stages of growth and that the sooner they disappear from a region the sooner has this region passed through a given stage of development, hence the "earlier" is this region.

The shoulder of lamb No. 54 at 1 month old, Pl. IV*a*, has black coarse hairs at the end of the staple, but they extend over a little less than half the length, the rest being white. On the other hand, in lamb No. 55, Pl. V*a*, at 1 month old and at the same site the white portion of the staple takes up only the lower quarter approximately; a clearly black portion takes up approximately the upper half, and between the part that is clearly white and the black part there is a portion of intermediate colour composed either of fibres slightly brown in colour or of a mixture of coloured fibres with white ones, or the white fibres are much more numerous than at the end of the staple. This means that the shoulder in the two lambs produces at a certain period of its development fibres very similar in composition and in the way they are mixed, but that one of them (No. 54) subsequently begins to produce white fibres, or less coloured ones, in greater abundance. The shoulder of lamb No. 54 begins to produce white fibres abundantly at an earlier stage of development than that of lamb No. 55, or else the shoulder of No. 55 begins to produce black hairs before that of lamb No. 54, while beginning to produce white fibres at about the same time. Although the facts given here are not of the kind to decide the question, it is very interesting to observe, Pls. IV*a* and V*a*, that in the staple severed at 1 month old (25 January 1936) the black or coloured portion has a much greater absolute length in lamb No. 55 than in No. 54, whilst the white portions are of approximately the same length. The fact is very clearly seen in the other regions and the principle also applies in general when the fibres are studied individually. In the legs and the belly the difference in the length of the black part in lambs Nos. 55 and 54 is remarkable. It is important to note that the later a region is in development, the greater is this difference between the length and the percentage of coarse and coloured fibres in a good (No. 54) and an inferior (No. 55) lamb, especially at the later stages of development.

An improved animal would therefore be one in which (1) the latest developing parts of the fleece would have the least possible undesirable fibres at the earliest possible age, even during the embryonic stage; and (2) the undesirable fibres would begin to appear in the embryo as late as possible. Apparently when the undesirable fibres begin to develop early they remain longer on the region. Since ontogenetic development is a repetition of phylogenetic development, in the light of what we have just seen, one may state that the breeds of sheep begin their improvement by changes in the earliest developing region (the shoulder) and will finish it by changes in the latest developing region (the tail). This agrees with the observation that can be made in studying the difference between the qualities of the wool of different regions in the ordinary animals of a given breed, and comparing them with highly improved animals of the same breed. In the ordinary animals one finds in the areas characterized by early development (shoulder, back) types of wool of which the quality sometimes exceeds the wool of highly improved animals of the breed; on the other hand in the late developing parts (legs) the qualities of the wool improve much more slowly, and wide differences are found between the highly improved and the ordinary animals.

II. THE DEVELOPMENT OF CERTAIN WOOL CHARACTERS IN THE DIFFERENT REGIONS

(*a*) *The colour of the fibres*

(1) *The intensity of the colour.* The intensity of the colour ranges from fibres very slightly coloured here and there by faint brown spots or stripes to fibres so dark that the light cannot pass through them at all when they are examined by a microscope with transmitted light, and in spite of the relatively great degree of fineness of certain fibres they are seen as completely opaque. We have arbitrarily classed the shades of the fibres into six kinds according to a scale drawn up by us namely: white fibres, slightly brown, brown, dark brown, black, and deep black.

(2) *The distribution of the shades along the length of the fibre.* One finds fibres that are entirely white, fibres entirely coloured, and numerous fibres quite black in the upper portion and quite white in the lower portion, showing that the same follicles can produce both black and white fibres. Sometimes in fibres that are coloured and constricted at some place one finds the constricted portion is white and the rest is black. The

black in this case passes into white after having passed successively through a series of colours which become lighter in shade as the fibre becomes gradually thinner.

Hence there are several sorts of follicles, (1) those which can produce only white fibres even before birth, (2) those which produce black fibres even a long time after birth, (3) those which produce black fibres before birth or during very active periods of growth and then when these periods are over produce white fibres constantly, (4) those which can produce alternatively white fibres or coloured ones of different shades.

(3) *Distribution of the various shades in the staple and in the different regions of the skin.* Tables I and II give in a summarized form an idea of how the colours are distributed in relation to each of the grades of fineness of the fibres, and the average fineness of each of the shades. These tables also show the percentage of fibres of different colours present at different ages and in the different regions. It will be seen from these tables that the fleece as a whole loses its dark colour first of all and primarily owing to a decrease in the coloured fibres in general and an increase in the white fibres and subsequently owing to a reduction in the ratio of strongly coloured fibres to weakly coloured ones, which may correspond to variations in the concentration in the same follicle (second case) and to the loss of coloured hairs with age (first case). The follicles with white fibres are really incapable of acquiring pigment whatever the conditions of growth may be, once the follicle is completely formed. In the portion of the fibre which has been formed while the follicle has not yet completed its development, i.e. while the point of the fibre has not yet been pushed out, brown colourations are produced in the fibres, even in those which later are entirely white—a fact which we observed in studying the tapered portion of the end of the fibres. But this type of follicle, once formed, loses completely its capacity to produce pigmented fibres. It is by the relative increase in the number of these follicles in proportion to the coloured ones or by some other important change that the modifying gene takes effect during the course of development. It is probable that it acts upon the coloured fibres (suppression or modification), and not by increasing the number of white fibres. The fact that the point of the white fibres is coloured to the very tip indicates that though these fibres are composed of cells which under normal conditions do not become pigmented, they are, nevertheless, not thus characterized at the time when they are dividing very actively during the formation of the follicle. The genes or factors which control the degree of colouration of the fibres might be, at

Table I. *Lamb No.* 54. *Distribution in diameter* (7·5 = 10 μ) *of different coloured fibres in the fleece in different body regions and at different ages*

Body region	Date	Colour of fibre	Fibres		No. of fibres with diameter of												Av. fibre diameter
			Total	%	−8	−13	−18	23	28	33	38	43	48	53	58	63	
Shoulder	25. i. 36	White	365	92	5	128	206	26	.	.	.	.	.	.	.	.	17
		Brown (1)	28	7	.	24	4	.	.	.	.	.	.	.	.	.	14
		Black (2)	4	1	.	2	2	.	.	.	.	.	.	.	.	.	16
	21. iii. 36	White	392	95	1	64	255	69	3	.	.	.	.	.	.	.	18
		Brown	19	4	1	11	7	.	.	.	.	.	.	.	.	.	15
		Black	3	1	1	1	1	.	.	.	.	.	.	.	.	.	13
	16. v 36	White	387	96	1	45	252	84	5	.	.	.	.	.	.	.	19
		Brown	12	3	.	5	6	1	.	.	.	.	.	.	.	.	16
		Black	2	1	.	2	.	.	.	.	.	.	.	.	.	.	13
Leg	25 i. 36	White	349	87	2	65	159	109	13	1	.	.	.	.	.	.	19
		Brown	44	11	.	27	15	2	.	.	.	.	.	.	.	.	15
		Black	7	2	.	4	3	.	.	.	.	.	.	.	.	.	15
	21. iii. 36	White	377	94	1	8	83	168	105	11	1	.	.	.	.	.	23
		Brown	12	3	1	4	6	1	.	.	.	.	.	.	.	.	16
		Black	11	3	.	.	6	5	.	.	.	.	.	.	.	.	20
	16. v. 36	White	388	98	.	8	89	219	60	12	.	.	.	.	.	.	23
		Brown	5	1	.	3	2	.	.	.	.	.	.	.	.	.	15
		Black	3	1	.	.	3	.	.	.	.	.	.	.	.	.	18
Belly	21. iii. 36	White	327	80	6	126	184	11	.	.	.	.	.	.	.	.	16
		Brown	43	10	3	17	23	.	.	.	.	.	.	.	.	.	15
		Black	40	10	.	2	18	18	3	.	.	.	.	.	.	.	21
Tail	25. i. 36	White	307	70	.	2	61	93	79	56	11	5	.	.	.	.	26
		Brown	74	17	.	7	34	25	7	1	.	.	.	.	.	.	21
		Black	57	13	.	2	5	18	17	13	1	1	.	.	.	.	27

(1) Includes light brown, brown and dark brown.

(2) Includes black and deep black.

Table II. *Lamb No.* 55. *Distribution in diameter* ($7 \cdot 5 = 10 \mu$) *of different coloured fibres in the fleece in different body regions and at different ages.*

Body region	Date	Colour of fibre	Fibres		No. of fibres with diameter of														Av. fibre diameter
			Total	%	−8	−13	−18	−23	−28	−33	−38	43	48	53	58	63	68	73	
Shoulder	25. i. 36	White	286	57	1	88	163	31	3	.	.	.	.	.	.	.	.	.	17
		Brown (1)	108	21	2	85	18	2	1	.	.	.	.	.	.	.	.	.	14
		Black (2)	9	2	.	2	5	1	.	.	1	.	.	.	.	.	.	.	20
	21. iii. 36	White	371	93	.	43	195	117	15	1	.	.	.	.	.	.	.	.	19
		Brown	30	7	3	19	8	.	.	.	.	.	.	.	.	.	.	.	14
		Black	0	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	—
	16. v. 36	White	408	97	2	57	203	145	21	1	.	.	.	.	.	.	.	.	20
		Brown	11	3	.	10	1	.	.	.	.	.	.	.	.	.	.	.	13
		Black	0	0	.	.	1	.	.	.	.	.	.	.	.	.	.	.	18
Leg	25. i. 36	White	208	52	.	19	105	69	13	2	.	.	.	.	.	.	.	.	20
		Brown	127	32	3	45	68	9	1	1	.	.	.	.	.	.	.	.	17
		Black	64	16	.	12	19	6	9	3	4	4	5	1	.	1	.	.	26
	21. iii. 36	White	343	83	.	4	63	127	101	31	15	1	1	.	.	.	.	.	25
		Brown	35	9	.	12	13	6	.	.	.	2	2	.	.	.	.	.	20
		Black	35	8	.	1	2	8	9	6	3	3	.	3	.	.	.	.	31
	16. v. 36	White	392	93	1	10	85	155	113	25	3	.	.	.	.	.	.	.	24
		Brown	3	1	1	2	.	.	.	.	.	.	.	.	.	.	.	.	11
		Black	27	6	.	4	8	12	2	.	.	1	.	.	.	.	.	.	21
Belly	21. iii. 36	White	286	72	1	51	171	37	8	5	6	6	1	.	.	.	.	.	19
		Brown	42	11	1	23	10	4	1	.	3	.	.	.	.	.	.	.	17
		Black	70	17	1	5	27	18	10	6	3	.	.	.	.	.	.	.	23
Tail	25. i. 36	White	155	39	5	1	2	24	28	26	19	29	11	6	4	.	.	.	34
		Brown	95	24	.	.	17	24	4	5	10	14	11	6	2	.	1	1	34
		Black	146	37	.	3	6	16	28	29	21	13	9	11	7	1	1	1	36

(1) Includes light brown, brown and dark brown. (2) Includes black and deep black.

least to some extent, those which might control the rapidity of the division of the cells.

On the other hand, the follicles capable of producing different shades in the fibres may undergo changes by factors acting upon the follicle, not during its formation but at a more or less advanced stage of development of the lamb, and are more strongly influenced by physiological factors than the other follicles. We shall term the factors acting upon the follicles with white fibres "qualitative" factors and those acting upon follicles capable of producing different shades, "quantitative" factors. There are also the fibres that are clearly black at the tip and then quite white starting from a well-defined point. As regards these the interpretation of the phenomenon is more complex, though it is probable that it, like the others, is connected with the rapidity of development.

Tables I and II give the reader an idea of how the various shades and colours are distributed in the regions of the skin and according to the fineness of the fibres at different stages of development. Passing from the regions with the earlier development to those with a later development it is seen that for each stage there is, at a given time in the development, a corresponding definite shade of fibres which are more numerous than the others but which, above all, are seen to be more regularly distributed so that they tend to give a regular frequency curve with one peak. Furthermore, these shades "characteristic" of each region become in general darker and darker as one passes from the "early" to the "late" regions.

The shades that show the most regular curves for the various regions are as follows:

Lamb	Region	Date	Colour which displays the most regular curve
Lamb No. 54	Shoulder	25. i. 36	Light brown and brown
	Leg	25. i. 36	Brown
	Belly	21. iii. 36	Dark brown
	Tail	25. i. 36	Deep black
Lamb No. 55	Shoulder	25. i. 36	Brown
	Shoulder	21. iii. 36	Brown and dark brown
	Leg	25. i. 36	—
	Leg	21. iii. 36	Brown and dark brown
	Belly	21. iii. 36	Brown and black
	Tail	25. i. 36	Black

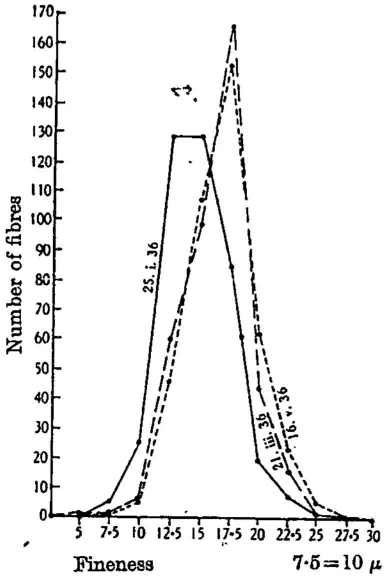
In our opinion this shows once again the relation that exists between the development of the region and the capacity for the production of colour in the fibres. The white fibres always exhibit rather regular curves.

The percentage of fibres of the different shades varies greatly from one grade of fineness to another. Hence the factors acting upon the shades of the colours do not behave in the same way as regards the fibres of different degrees of fineness. The different trend of the curves representing the fibres of black colour (see Tables I and II) and those of lighter colouration suggests that the nature of the factor (or factors) determining the colour deep black must be different from that of the lighter shades. This finding is specially marked in the tail region of lamb No. 55. It seems to us probable that the pigment of the deep black fibres is not only quantitatively but also qualitatively different from that of fibres with lighter colours. Thus the brown fibres probably become lighter simply owing to the dilution of the pigment; whereas in the deep black fibres there is possibly a physico-chemical or a chemical change in the pigment or the substance forming its substratum.

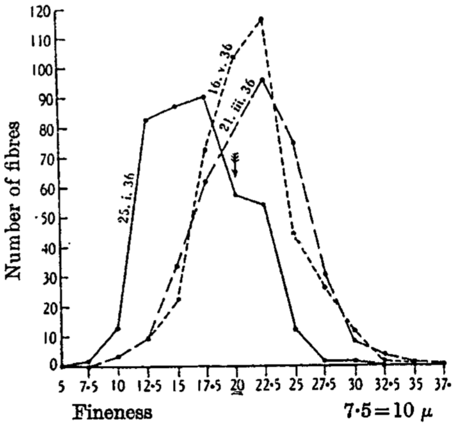
(*b*) *Medullated fibres*

We have divided the fibres according to the greater or smaller proportion of medulla observed in them on microscopic examination into four types: (1) fibres exhibiting no medulla (type A); (2) fibres with an intermittent medulla (type B); (3) fibres with a continuous medulla occupying about 80 % of the thickness of the fibre (type C); and (4) fibres having over 80 % medulla (type D).

The reader may obtain an idea of the proportion of these various types



Text-fig. 1 (*a*). Lamb 54, shoulder.



Text-fig. 1 (*b*). Lamb 54, leg.

in the different regions of the skin by studying Table III, noting, however, that the figures are only approximate owing to the difficulty of distinguishing the medulla in fibres of shades that are too dark.

It is interesting to observe that in the fibres possessing a medulla the fibres tend to increase in diameter by an increase in the diameter of the medulla and not by increasing the size of the cortical portion which tends to remain practically the same.

It should also be noted that in the belly region there are relatively few fibres with a medulla although it is a region that develops late.

Table III. *Distribution in diameter* ($7{\cdot}5=10\mu$) *of the medullated and non-medullated fibres of different sorts in the different regions of the body at different ages*

				No. of fibres with diameter of													
Lamb	Body region	Date	Type of fibre	−8	−13	−18	−23	−28	−33	−38	−43	−48	−53	−58	−63	−68	−73
54	Shoulder	25. i. 36	A	5	152	212	26	1	.	1	.	.	.	.	.	.	.
			C	.	1	.	.	.	.	.	.	.	.	.	.	.	.
	Shoulder	21. iii. 36	A	3	66	263	69	3	.	.	1	.	.	.	.	.	.
	Shoulder	16. v. 36	A	1	52	258	85	5	.	.	.	.	.	.	.	.	.
	Leg	25. i. 36	A	2	96	161	64	3	.	.	.	.	.	.	.	.	.
			B	.	.	11	34	3	.	.	.	.	.	.	.	.	.
			C	.	.	5	15	7	1	.	.	.	.	.	.	.	.
	Leg	21. iii. 36	A	2	12	94	157	86	9	1	.	.	.	.	.	.	.
			B	.	.	1	17	18	2	.	.	.	.	.	.	.	.
			C	.	.	.	.	1	.	.	.	.	.	.	.	.	.
	Leg	16. v. 36	A	.	11	94	219	70	12	.	.	.	.	.	.	.	.
	Belly	21. iii. 36	A	8	146	239	27	3	.	.	.	.	.	.	.	.	.
	Tail	25. i. 36	A	.	9	100	136	74	31	2	4	.	.	.	.	.	.
			B	.	.	.	.	20	26	4	1	.	.	.	.	.	.
			C	.	.	.	.	9	13	5	1	.	.	.	.	.	.
55	Shoulder	25. i. 36	A	3	175	182	13	4	.	1	.	.	.	.	.	.	.
			B	.	.	4	1	.	.	.	.	.	.	.	.	.	.
	Shoulder	21. iii. 36	A	3	62	203	120	15	1	.	.	.	.	.	.	.	.
			B	.	.	1	.	.	.	.	.	.	.	.	.	.	.
	Shoulder	16. v. 36	A	2	40	205	145	21	4	4	4	5	1	1	.	.	.
			C	.	.	.	.	.	2	.	.	.	.	.	.	.	.
	Leg	25. i. 36	A	2	78	182	46	14	.	.	.	.	.	.	.	.	.
			B	1	2	10	25	5	.	.	.	.	.	.	.	.	.
			C	.	.	1	9	4	.	.	.	.	.	.	.	.	.
	Leg	21. iii. 36	A	.	17	74	102	59	15	9	2	.	2	1	.	.	.
			B	.	.	4	36	34	9	2	.	.	.	.	.	.	.
			C	.	.	.	3	17	11	5	2	1	.	.	.	.	.
			D	.	.	.	.	.	1	3	2	.	1	.	.	.	.
	Leg	16. v. 36	A	2	16	93	166	109	24	3	1	.	.	.	.	.	.
			B	.	.	.	1	5	1	.	.	.	.	.	.	.	.
	Belly	21. iii. 36	A	3	79	208	58	19	8	4	.	.	.	.	.	.	.
			C	.	.	.	.	.	3	8	6	1	.	.	.	.	.
	Tail	25. i. 36	A	4	4	25	63	52	40	31	21	8	14	9	1	2	2
			B	1	.	.	1	5	5	1	2	3	1	.	.	.	.
			C	.	.	.	.	2	14	19	31	20	7	4	.	.	.
			D	.	.	.	.	.	.	.	1	.	.	.	.	.	.

A = Fibres with no medulla.
B = Fibres with an intermittent medulla.
C = Fibres with a continuous medulla occupying under 80 % of the fibre thickness.
D = Fibres having a medulla of over 80 % of their thickness.

in the different regions of the skin by studying Table III, noting, however, that the figures are only approximate owing to the difficulty of distinguishing the medulla in fibres of shades that are too dark.

It is interesting to observe that in the fibres possessing a medulla the fibres tend to increase in diameter by an increase in the diameter of the medulla and not by increasing the size of the cortical portion which tends to remain practically the same.

It should also be noted that in the belly region there are relatively few fibres with a medulla although it is a region that develops late.

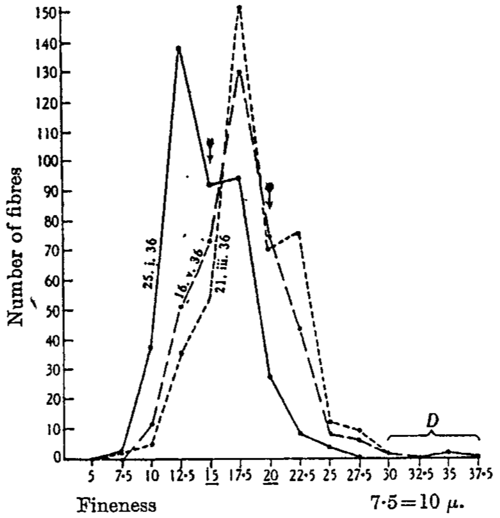
Table III. *Distribution in diameter* ($7{\cdot}5 = 10\,\mu$) *of the medullated and non-medullated fibres of different sorts in the different regions of the body at different ages*

Lamb	Body region	Date	Type of fibre	No. of fibres with diameter of													
				−8	−13	−18	−23	−28	−33	−38	−43	−48	−53	−58	−63	−68	−73
54	Shoulder	25. i. 36	A	5	152	212	26	1	.	1	.	.	.	.	.	.	.
			C	.	1	.	.	.	.	.	.	.	.	.	.	.	.
	Shoulder	21. iii. 36	A	3	66	263	69	3	.	.	1	.	.	.	.	.	.
	Shoulder	16. v. 36	A	1	52	258	85	5	.	.	.	.	.	.	.	.	.
	Leg	25. i. 36	A	2	96	161	64	3	.	.	.	.	.	.	.	.	.
			B	.	.	11	34	3	.	.	.	.	.	.	.	.	.
			C	.	.	5	15	7	1	.	.	.	.	.	.	.	.
	Leg	21. iii. 36	A	2	12	94	157	86	9	1	.	.	.	.	.	.	.
			B	.	.	1	17	18	2	.	.	.	.	.	.	.	.
			C	.	.	.	.	1	.	.	.	.	.	.	.	.	.
	Leg	16. v. 36	A	.	11	94	219	70	12	.	.	.	.	.	.	.	.
	Belly	21. iii. 36	A	8	146	239	27	3	.	.	.	.	.	.	.	.	.
	Tail	25. i. 36	A	.	9	100	136	74	31	2	4	.	.	.	.	.	.
			B	.	.	.	.	20	26	4	1	.	.	.	.	.	.
			C	.	.	.	.	9	13	5	1	.	.	.	.	.	.
55	Shoulder	25. i. 36	A	3	175	182	13	4	.	1	.	.	.	.	.	.	.
			B	.	.	4	1	.	.	.	.	.	.	.	.	.	.
	Shoulder	21. iii. 36	A	3	62	203	120	15	1	.	.	.	.	.	.	.	.
			B	.	.	1	.	.	.	.	.	.	.	.	.	.	.
	Shoulder	16. v. 36	A	2	40	205	145	21	4	4	4	5	1	1	.	.	.
			C	.	.	.	.	.	2	.	.	.	.	.	.	.	.
	Leg	25. i. 36	A	2	78	182	46	14	.	.	.	.	.	.	.	.	.
			B	1	2	10	25	5	.	.	.	.	.	.	.	.	.
			C	.	.	1	9	4	.	.	.	.	.	.	.	.	.
	Leg	21. iii. 36	A	.	17	74	102	59	15	9	2	.	2	1	.	.	.
			B	.	.	4	36	34	9	2	.	.	.	.	.	.	.
			C	.	.	.	3	17	11	5	2	1	.	.	.	.	.
			D	.	.	.	.	.	1	3	2	.	1	.	.	.	.
	Leg	16. v. 36	A	2	16	93	166	109	24	3	1	.	.	.	.	.	.
			B	.	.	.	1	5	1	.	.	.	.	.	.	.	.
	Belly	21. iii. 36	A	3	79	208	58	19	8	4	.	.	.	.	.	.	.
			C	.	.	.	.	.	3	8	6	1	.	.	.	.	.
	Tail	25. i. 36	A	4	4	25	63	52	40	31	21	8	14	9	1	2	2
			B	1	.	.	1	5	5	1	2	3	1	.	.	.	.
			C	.	.	.	.	2	14	19	31	20	7	4	.	.	.
			D	.	.	.	.	.	.	.	1	.	.	.	.	.	.

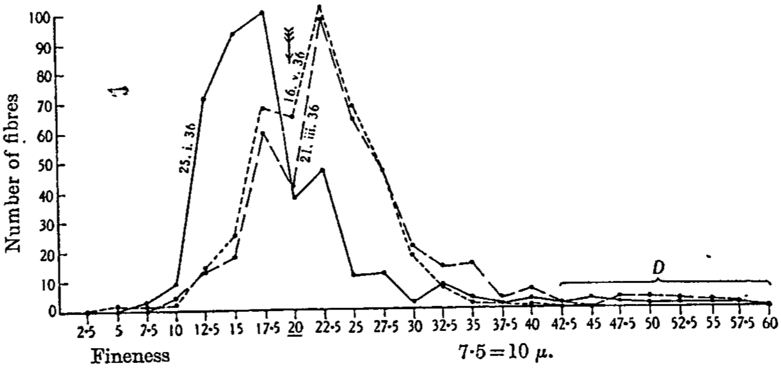
A = Fibres with no medulla.
B = Fibres with an intermittent medulla.
C = Fibres with a continuous medulla occupying under 80 % of the fibre thickness.
D = Fibres having a medulla of over 80 % of their thickness.

(*c*) *Fineness*

It is seen in Text-fig. 1*a* and 1*b* showing the frequency curves for the degrees of fineness for the shoulder and the leg, respectively, of lamb No. 54 and in Text-fig. 2*a* and 2*b* representing the corresponding data for lamb No. 55 that there is a wide difference between the degrees of fineness of the fibres at 1 month old and those which grow during the later periods of development. In Text-fig. 1*a* we see that the frequency curve for the shoulder on the dates 21 March 1936 and 16 May 1936 remains almost the same; hence this region already no longer varies at



Text-fig. 2 (*a*). Lamb 55, shoulder.



Text-fig. 2 (*b*). Lamb 55, leg.

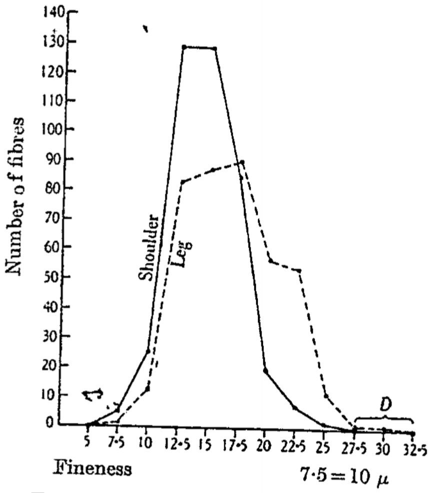
this period for lamb No. 54. The curve for lamb No. 55 at the shoulder on the same dates, Text-fig. 2*a*, also appears to show little development, if we consider the general trend of the curve without considering the details. Note, however, that (*a*) the two curves, those representing the wool sheared on 21 March 1936 and that on 16 May 1936, exhibit a greater difference *inter se* than those of lamb No. 54 in the region with the coarse fibres (indicated by a *D* in the figure); (*b*) the curve for 21 March 1936 (and similarly that for 25 January 1936) exhibits a depression at the place marked with an arrow, whilst the curve for 16 May 1936, shows no depression and resembles the curves for lamb No. 54 for the same dates. Judging from this, therefore, development as regards fineness in this animal for the shoulder would not be completed till between the third and fifth months after birth, whereas in the other animal development should already be almost completed at this period. It is an interesting fact that the depressions of importance in all the curves are always found opposite the number 20 and sometimes 15 representing the scale of fineness. The same phenomenon is found in adult animals showing one less cross of Suffolk blood.

The same methods applied to the wool of the leg, using the same criterion to estimate the "earliness" of a region, show us that the leg of lamb No. 54, Text-fig. 1*b*, and the leg of lamb No. 55, Text-fig. 2*b*, also exhibit the same differences, but more accentuated. Thus the curve representing the leg of No. 54 exhibits a depression on 25 January 1936 and those for the dates 21 March 1936 and 16 May 1936 no longer show a depression. They display a similar trend and show little difference in the region of the coarse fibres (*D*); whereas lamb No. 55, Text-fig. 2*b*, shows similar trends on the dates 21 March 1936 and 16 May 1936 and the curves display, like the curve for the wool at birth, a well-marked depression, thus showing that the fibres have not entirely completed their development as regards the degrees of fineness. On the other hand, the difference (*D*) between the degrees of fineness in the regions of the curve with coarse fibres is very great.

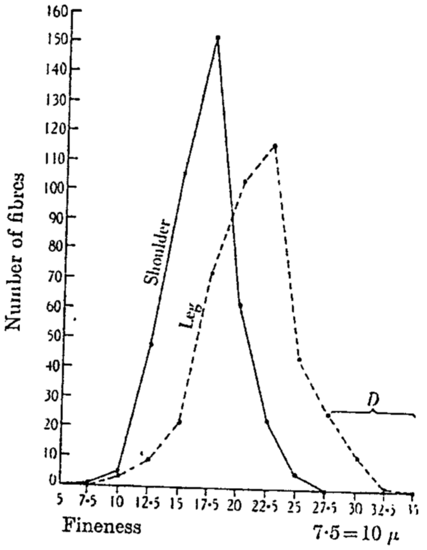
These facts lead us to the view that when one wishes to determine the value of the fleece of sheep for breeding, on the basis of the frequency curves for fineness, one must eliminate the individuals displaying depressions in the curves, and deviations in the regions of the coarse fibres. In this respect a study by means of frequency curves is one of more value than a study by means of calculations of the average fineness, coefficient of variation, etc.

(*d*) *Uniformity of fibre size*

From the commercial standpoint the importance of obtaining a uniform fleece is well known. Breeders obtain an idea of the uniformity of the fleece by examination of a part characterized by "early" development (shoulder) and a part characterized by late development (the leg). Although in principle the method is good, since, without knowing it, they compare "early" regions with "late" ones, the method is subject to a certain criticism in the light of the facts considered above. Thus in a breed in which the leg is highly evolved it would be best, for example, to examine a part still "later" such as the tail. We observe in Text-figs. 3*a* and 3*b* representing the frequency curves for the shoulder and the leg of lamb No. 54 and Text-figs. 4*a* and 4*b* representing those for lamb No. 55 that the differences between the regions are not the same at both periods—a fact which was to be expected since the "early" regions develop more rapidly. The curves for lamb No. 54 (good lamb) for the date 16 May 1936 display, when reduced to numerical averages, differences as great and even greater between the shoulder and the leg than for lamb No. 55 (inferior lamb), and this is so as regards the fineness and the uniformity. On the other hand, if one considers only the deviations for the regions of the curves with coarse fibres (*D*), it is seen that in the curves of lamb No. 54 this difference is small and for No. 55 very large.



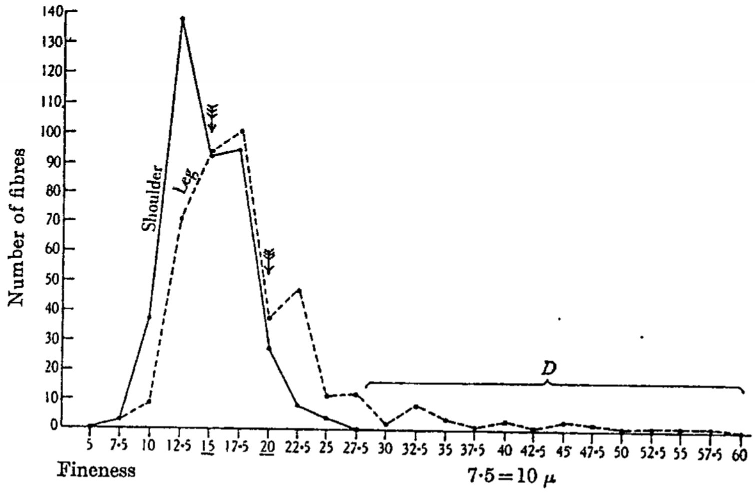
Text-fig. 3 (*a*). Lamb 54, 25. January 36.



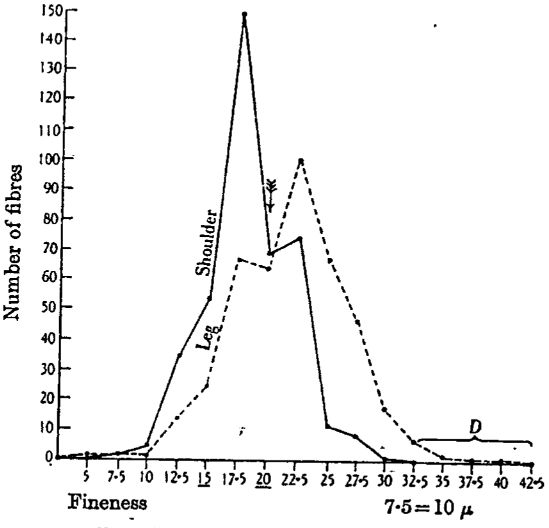
Text-fig. 3 (*b*). Lamb 54, 16 May 36.

III. THE BEST REGION FOR JUDGING THE VALUE OF THE WOOL IN LAMBS

The differences between the qualities of the wool from the same region of the skin in two different individuals is not the same (or, in other words, does not remain constant) during the course of development. This fact can be seen by comparing Text-figs. 1*b* and 2*b*.



Text-fig. 4 (*a*). Lamb 55, 25 January 36.



Text-fig. 4 (*b*). Lamb 55, 16 May 36.

When one is judging the wool value of a future breeding animal on the basis of the examination of its fleece as a lamb the best part for such an examination will depend upon: (1) the stage of development—more or less advanced—at the time of examination; (2) the "earliness" of the breed examined; (3) the degree of improvement attained by the breed as regards wool qualities. At an early stage of development the two regions are very similar, later one of these regions developing more rapidly in the early maturing animal than in the other, they will display the maximum of differences, one of these regions still retaining the coarse fibres and the other (those of the improved animal) having shed them. Later still the regions resemble each other a little, but then the differences that remain are final.

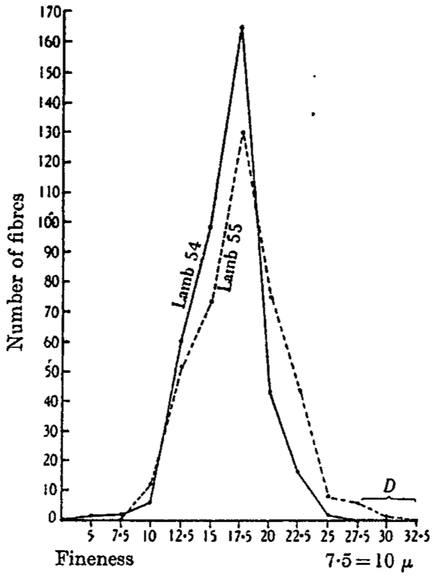
It is of considerable interest to breeders to determine which is the best region for the examination of lambs at the time when the tails are being docked. The best animal will be the one which develops more rapidly in the "latest" developing of these regions. It should be noted that examination of the lamb as compared with the examination of the adult has the advantage of giving us some idea of its genetic constitution, revealing to us defects which would be concealed later; one might therefore term this method a "phaeno-genetic" method much less complicated, certainly, than the methods used or suggested up to the present.

In this case the lambs from the cross (Suffolk × Suffolk (Border Leicester-Cheviot)) display at the time of docking (one month old) the maximum of differences in the tail region, as the reader can observe from an examination of Text-fig. 5*b* and a comparison of it with Text-fig. 5*a* representing the differences for the shoulder. Pl. VI shows us a classification made with a series of tails of this cross classed according to the wool value of the lambs. One can very clearly see the difference merely by macroscopic examination. For a better estimation of the value it is well to note that the middle of the tail is the site of the better wool. The edges are very hairy and the end still more so. If the tail is turned round with the underside outwards the hairs are still more numerous and coarser.

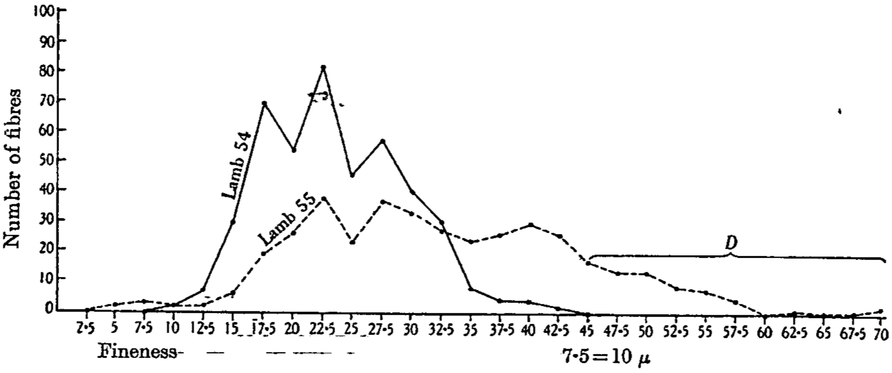
SUMMARY

1. A study has been made of the relative development of some regions in the fleece of twin lambs of a Suffolk ♂ × Suffolk (Border Leicester-Cheviot) ♀ cross during growth. The different regions develop in the following order: shoulder → leg → belly → tail. It is concluded that an

improved animal is one in which the latest developing part of the fleece has the least possible number of undesirable fibres at the earliest possible age. The breeds of sheep begin their wool improvement by changes in the earliest developing regions (shoulder) and finish it in the latest (tail).



Text-fig. 5 (*a*). Shoulder.



Text-fig. 5 (*b*). Tail.

2. The properties of the fleece studied were the colour of the fibres, the medullated fibres, the fineness of the fibres, and uniformity of fibre size. In general a relationship is found between the stage and rapidity of development of the area, and the properties of the fibre. The intensity

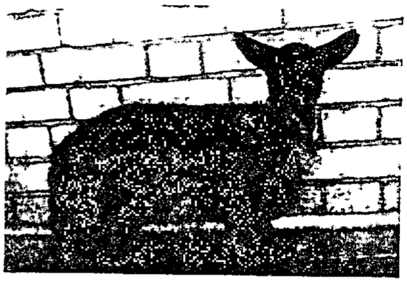


Fig. 1 (*a*). 2 weeks old.

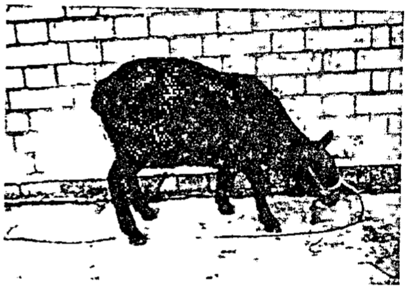


Fig. 1 (*b*). 2 months old.

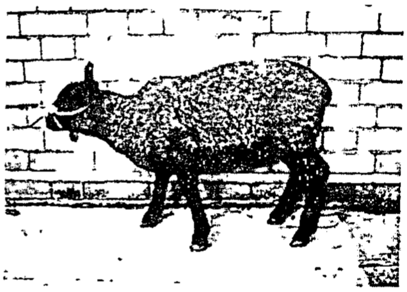


Fig. 1 (*c*). 3 months old.

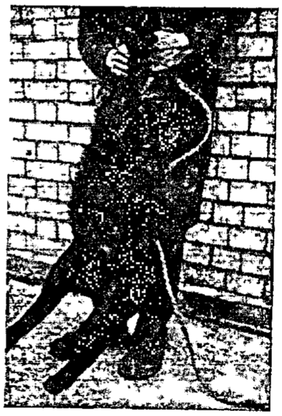


Fig. 1 (*d*). 3 months old.

Lamb No. 55.

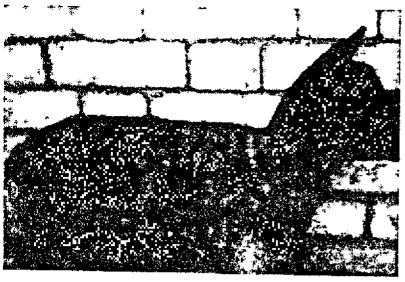


Fig. 2 (*a*). 2 weeks old.

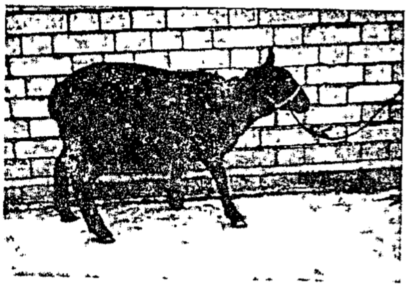


Fig. 2 (*b*). 2 months old.

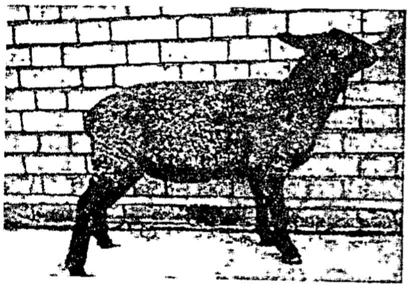


Fig. 2 (*c*). 3 months old.

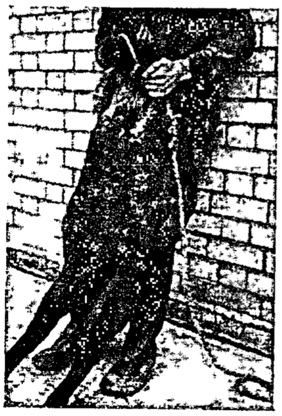
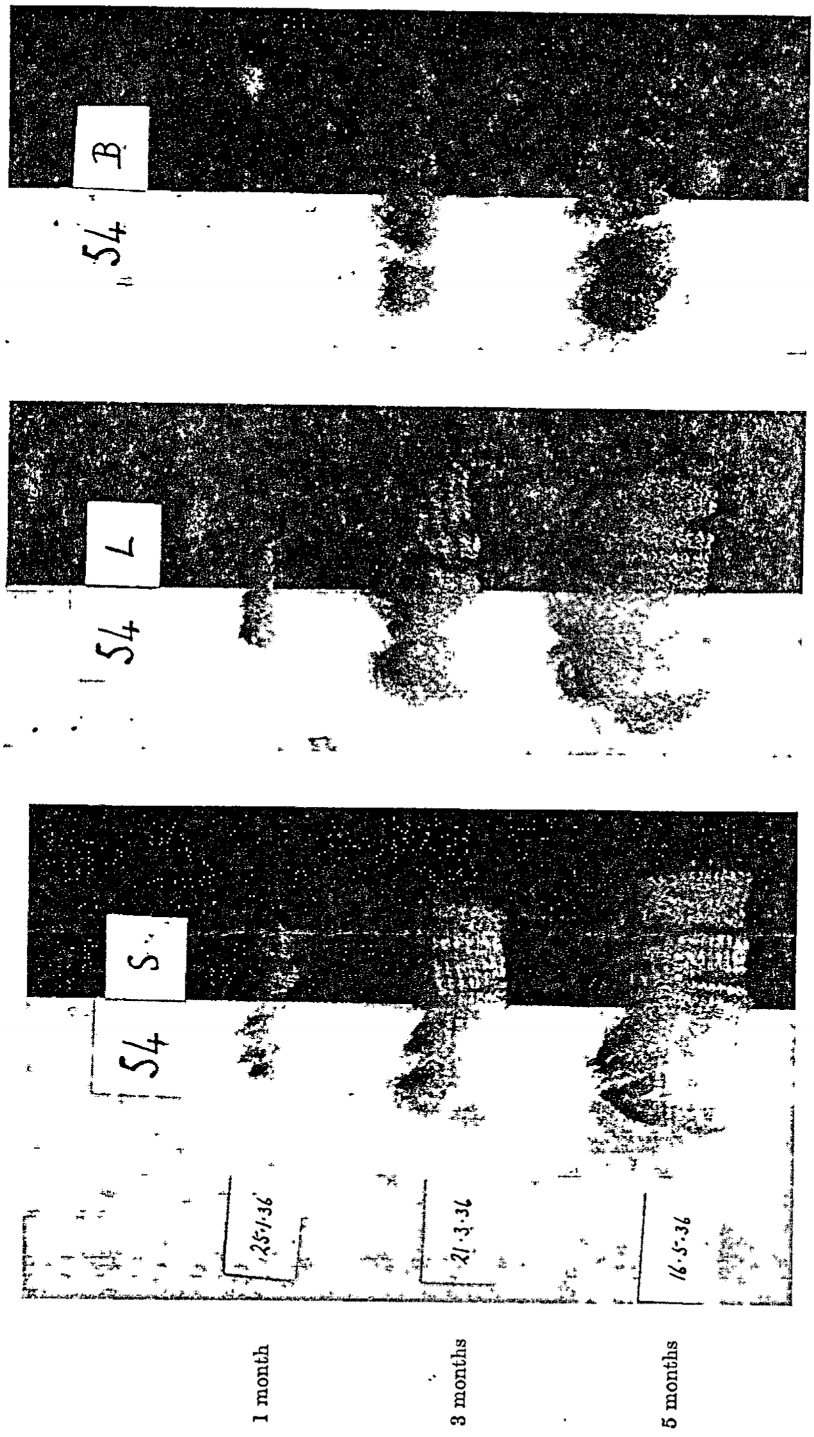


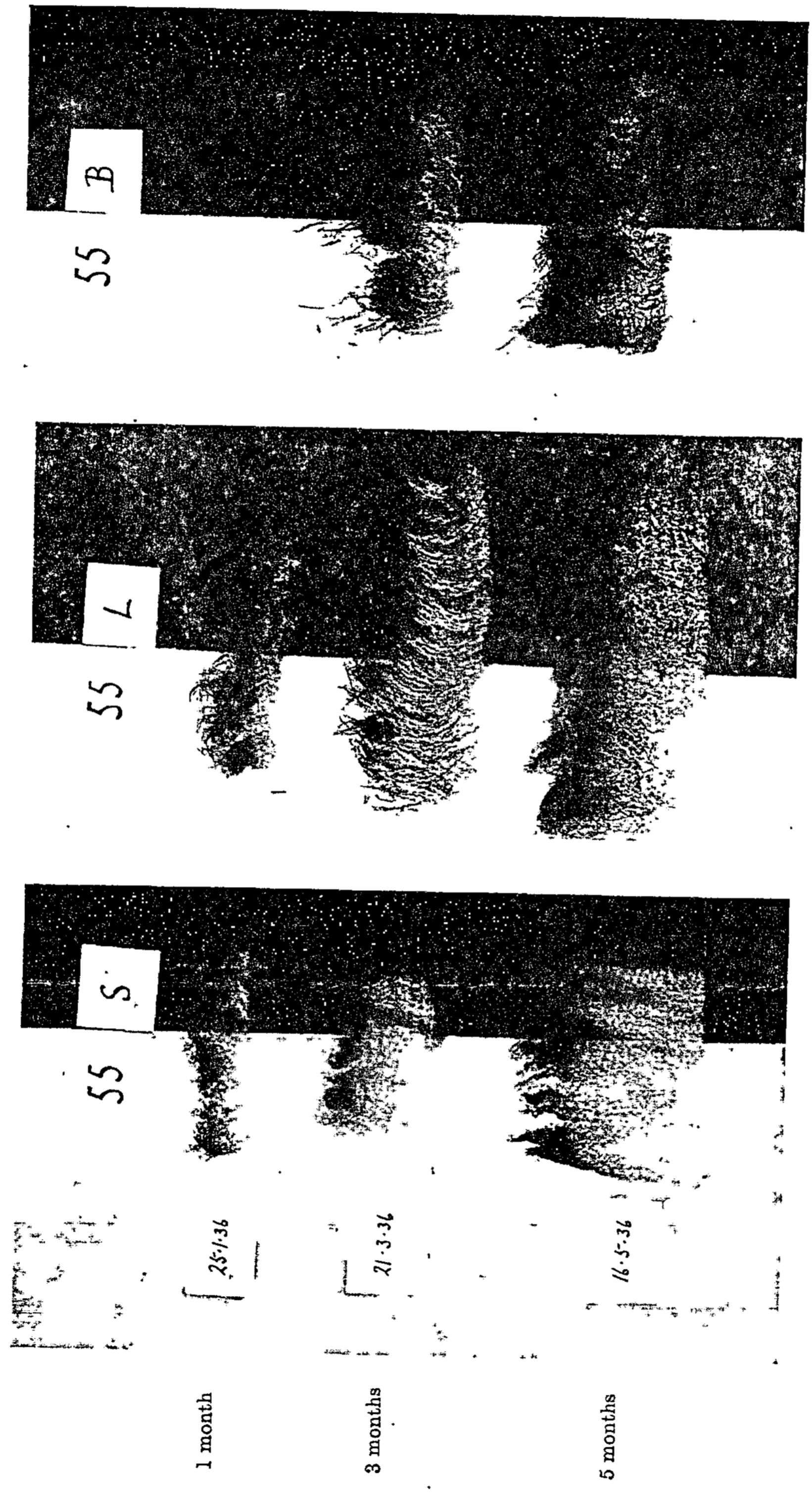
Fig. 2 (*d*). 3 months old.

Lamb No. 54.


54
B
54
L
54
S
25·1·36
21·3·36
16·5·36
1 month
3 months
5 months

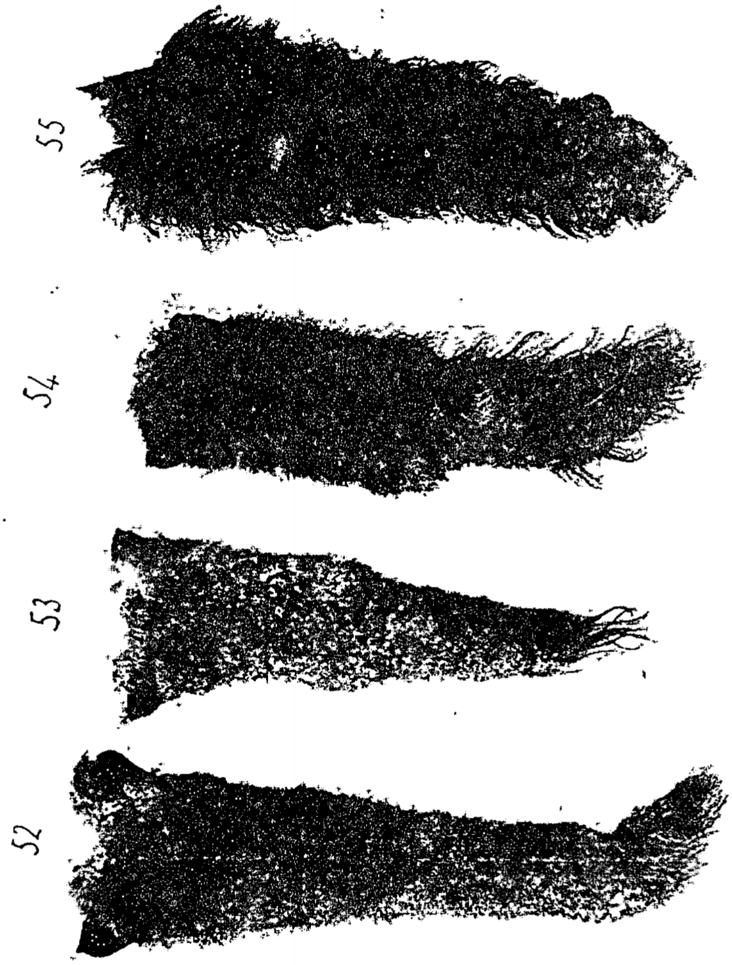
(a) Shoulder. (b) Leg. (c) Belly.

Lamb No. 54.


55 S
55 L
55 B
25·1·36
21·3·36
16·5·36
1 month
3 months
5 months

(a) Shoulder. (b) Leg. (c) Belly.

Lamb No. 55.


Lamb No.
52
53
54
55

Lambs' tails at 1 month old.

of the colour is stronger during the early active stages of development. There is a tendency to lose some kinds of coloured fibres, and to diminish the intensity of the colour in others as the development of each region in which the fibres grow proceeds.

The medullated fibres appeared in greatest quantities in the later developing regions, except the belly which presents few medullated fibres.

The staple is much finer at the first month of growth than in the later stages. Frequency curves of fibre size are of more value than average fibre size in estimating the value of the fleece.

3. It is suggested that the examination of the fleece of the lamb will give some idea of its genetic constitution and will reveal defects which would be concealed in the adult. Such a "phaeno-genetic" selection can be made best in a "late developing" area of the body such as the tail of the lamb at one month old.

I wish to express my gratitude to Dr Hammond who suggested this problem to me, indicated the techniques to use, and placed the experimental material at my disposal, and to whose kindness and hospitality I am indebted for having enabled me to carry out the work in his laboratory.

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